Journal of Stored Products Research 74 (2017) 66–77

Contents lists available at ScienceDirect

Journal of Stored Products Research

journal homepage: www.elsevier.com/locate/jspr

The repellent effect of plants and their active substances against the beetle storage pests

Małgorzata Kłyś [a,*], Natalia Malejky [a], Magdalena Nowak-Chmura [b]

[a] Pedagogical University of Cracow, Institute of Biology, Department of Ecology and Environmental Protection, Podbrzezie 3, 31-405 Kraków, Poland
[b] Pedagogical University of Cracow, Institute of Biology, Department of Invertebrate Zoology and Parasitology, Podbrzezie 3, 31-054 Kraków, Poland

ARTICLE INFO

Article history:
Received 28 December 2016
Received in revised form
21 September 2017
Accepted 8 October 2017

Keywords:
Repellent plant species
Bioassay techniques
Sitophilus oryzae
Tribolium castaneum
Oryzaephilus surinamensis
Rhyzopertha dominica
Sitophilus granaries

ABSTRACT

This review compares research techniques, plant species and forms of their application in worldwide studies on the repellent activity of plant material against storage pests, such as *Sitophilus oryzae*, *Sitophilus granarius*, *Tribolium castaneum*, *Rhyzopertha dominica* and *Oryzaephilus surinamensis*. Over 300 plant extracts, essential oils and powders were tested against these five insect species with various methods. The intensity of repellency of the examined plant products against each considered pest species was presented. Evaluation of the repellency potential of particular plant extracts, oils and powders showed that insect repulsion increased with their concentration. Duration of exposure was also an important factor affecting repellent activity.

Contents

1. Introduction

Worldwide food production is affected by huge losses incurred at its subsequent stages, from harvest, transport, storage, processing and packaging, until sale and consumption. It is estimated that each year in a global scale this great "chain of losses" generates

* Corresponding author. Tel.: +48 1266 26696; fax: +48 1266 27822.
E-mail address: klysgosia@poczta.onet.pl (M. Kłyś).

https://doi.org/10.1016/j.jspr.2017.10.006
0022-474X/

waste of 30–50% (1.2–2 bn tonnes) of the produced food, including 5–10% lost during storage. Reduction of such losses, particularly in the already harvested cereal plants, is more cost-effective than increase in food production (Fox, 2013).

Economic losses caused by storage pests are high, however, as they strongly vary with the type of crop, country, climatic region and duration of storage, they are difficult to measure. Moreover, no universal method has been developed for such assessment. Generally, global annual losses in the stored products due to insect activity are estimated at 10%. This global average is exceeded in some countries and e.g. in Ukraine the losses attain as much as 25–50%, however they are small in other states, e.g. in Australia they amount to only 0.7%. In Pakistan, 16% of wheat grain is lost during storage (Fox, 2013). In India, in the years of 2010–2011, food grain production attained 250 mlnn tonnes, nearly 20–25% of which were damaged by insect pests (Nattudurai et al., 2015). In Poland, losses in the stored cereal grains are estimated at 3–5% (Nawrot, 2001). According to Phillips and Throne (2010), post-harvest losses from stored-product insects range from up to 9% in developed countries to 20% and more in developing countries.

As much as 1660 insect species have been already identified as imposing a threat to agricultural products during their storage, processing, transport and advertising (Hagstrum and Subramanyam, 2009). The pests not only damage the stored cereals by feeding on and contaminating them, but also by moistening, heating and infecting the grains with fungi and bacteria. Moreover, proteins found in bodies, eggs, faeces and secretions of some storage insects may cause allergic reactions in people (Wirtz, 1991; Herling et al., 1995; Alanko et al., 2000; Arlian, 2002; Jakubas-Zawalska et al., 2016a,b).

Due to the worldwide spreading of these cosmopolitan pest species, generating huge economic losses and threatening human health, attempts are made to establish effective methods of pest control. However, common use of chemical agents, namely synthetic insecticides and fumigants, in the control of insect storage pests, resulted in serious problems such as development of insect resistance to insecticides (Zettler and Cuperus, 1990; Pereira et al., 1997; Ribeiro et al., 2003; Athie and Mills, 2005; Lorini et al., 2007), presence of toxic residues, harmful for the consumers, in food as well as increasing costs of agents application (Sighamony et al., 1990). For the above reasons, integrated pest management (IPM), taking advantage primarily of natural factors in prevention and control of storage pests, has become more popular. The method, involving both maintenance of appropriate sanitary conditions in the warehouse and its surrounding as well as capturing and repelling insects with semiochemicals, presently seems to be the safest way of pest control (Cox, 2004; Phillips and Throne, 2010).

More restrictive laws regulating pesticide application, greater social awareness of environmental and health issues and the increasing consumer demand for insect- and insecticide residue-free products motivate scientists to seek for alternatives to chemical methods in storage pest control. For a long time, plant agents have been recommended to be used instead of synthetic chemicals in integrated pest management, as phytochemical compounds are friendly for the environment and human health and their biological activity has been well documented in literature. Although the use of antifeedants in insect control has been widely investigated, particularly in laboratory tests, not many plant compounds are presently applied in agriculture (Weaver and Subramanyam, 2000; Koul, 2005, 2008).

The review by Nawrot and Harmatha (2012) provides a comparison of over 160 plant products (powders and extracts) tested by numerous authors as antifeedants against stored-product insects. Over 200 natural plant compounds from the tested species that appeared to display deterrent activity against stored-product insects were also identified and listed in the paper.

Presently, many studies carried out worldwide aim to evaluate the repellent activity of various natural substances against insect storage pests (Viglianco et al., 2008; Zhang et al., 2011; Akhtar et al., 2013; Yankanchi et al., 2014; Aref and Valizadegan, 2015). Such investigations basically involve different research methods, such as the Petri dishes method, cup bioassay technique, choice bioassay, multiple-choice bioassay, olfactometer as well as emigration and bi-directional migration, in which the plant material has been used in various concentrations and forms (powders, infusions, extracts, oils and essential oils) and has provided basis for diversified results.

This paper serves as a review and comparison of research techniques, plant species and forms of their application in world-wide studies on the repellent activity of such products against five species of insect storage pests *Sitophilus oryzae*, *Tribolium castaneum*, *Oryzaephilus surinamensis*, *Rhyzopertha dominica* and *Sitophilus granarius*. The intensity of repellency of the considered plant material was analysed as well.

2. Methods of testing

Reliability of results to be obtained in experiments evaluating the repellent and deterrent properties of phytochemical substances depends on numerous factors, such as temperature, relative humidity, light conditions, substrate for phytochemical substances, number and age of insects, as well as dose and duration of exposure to the applied product (Nawrot and Harmatha, 2012). In order to be effective, the tests should consider the biology of the examined storage pest and provide it with its optimum conditions.

Studies on the repellent effects of substances against stored-product insects involved various methods of using Petri dishes (Laudani et al., 1955; McDonald et al., 1970; Talukder and Howse, 1994; Ciepielewska et al., 2005; Shah et al., 2008; Viglianco et al., 2008; Jahromi et al., 2011; Lü et al., 2011), cup bioassay (Mohan and Fields, 2002; Pretheep Kumar et al., 2004; Popović et al., 2006; Shayesteh and Ashouri, 2010; Jahromi et al., 2011), choice bioassay (Loschiavo, 1952; Phillips et al., 1993; Pike et al., 1994; Bekele, 1995; Fields et al., 2001; Ogendo et al., 2003; Germinara et al., 2007; Wekesa et al., 2011), olfactometer (Pugazhvendan et al., 2009; Jahromi et al., 2011) and emigration and bi-directional migration (Kłyś, 2007).

2.1. Petri dishes

In this method, a filter paper disc cut into halves, one of which was treated with the examined substance and the other with the solvent, was placed in a Petri dish. Repellency could be assessed after putting the insects in the centre of the dish and subjecting them to the effect of the product. Shah et al. (2008) modified the method and replaced the filter paper with a nutrient medium. This procedure was used to evaluate the activity of e.g. water and water-alcohol extracts (Ciepielewska et al., 2005; Viglianco et al., 2008; Shah et al., 2008) as well as oils (Lü et al., 2011) and emulsions from plants (Jahromi et al., 2011). A different approach to the method using Petri dishes was applied by Wawrzyniak and Dębek-Jankowska (2010). In each Petri dish, they placed five plates with flakes prepared from wheat flour and distilled water, treated with tested plant extracts, and two control plates: one with a flake treated with solvent, and second – with a dry flake. Next, the beetles were put on the dishes. The dishes prepared in this way were then closed and their edges were sealed with petroleum jelly.

2.2. Cup bioassay

This method was based on unidirectional migration of insects.